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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : F16F 5/00, 9/00, 9/30, A62C 3/00, A41D 13/00, A43B 7/32, B60K 15/00, B60R 21/00, A62B 35/00, B64D 25/00, D06F 37/00 | A1

(11) International Publication Number: WO 99/49236

(43) International Publication Date: 30 September 1999 (30.09.99)

(21) International Application Number: PCT/GB98/03594

(22) International Filing Date: 2 December 1998 (02.12.98)

(30) Priority Data:

9805889.4	20 March 1998 (20.03.98)	GB
9812378.9	10 June 1998 (10.06.98)	GB

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(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

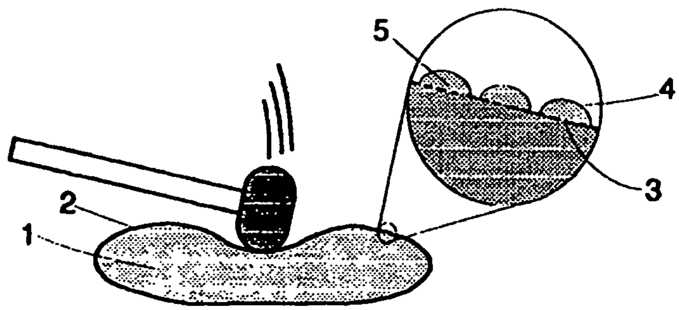
Published

With international search report.

(54) Title: IMPROVED ELASTOMERIC IMPACT ABSORBER WITH VISCOUS DAMPING

(57) Abstract

An elastic fluid filled impact absorber, that incorporates permeable barriers, to provide viscous damping. It can also include internal elastomeric solid or foam layers and an improved packaging design. In the figure, the elastic fluid (1), comprising a mixture of many small elastomeric capsules and a matrix liquid is enclosed in a package (2). The magnified view, which is shown on the right of the diagram depicts the structure of the package wall in more detail. Item (3) is part of the inner layer of the package wall and is a woven fabric which becomes permeable when a sufficiently high pressure difference exists across the layer. Item (4) is part of an elastic, impermeable outer membrane layer, which is strongly bonded to the inner layer at intervals in the manner of quilting. During violent impacts, liquid is driven through (3) and forms local liquid filled bubbles such as (5).



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Improved Elastomeric Impact Absorber with Viscous Damping

Technical Field

This invention relates to improvements in devices used as energy absorbers, to mitigate the undesirable effects of sudden blows or vibrations on bodies or machines.

According to the present invention, there is provided an impact or vibration absorbing device consisting of a deformable container or flexible package filled with a mixture of a liquid, grease or jelly fluid and a plurality of resilient capsules, with the device including one or more permeable barriers, characterised by the provision of viscous damping when some of the fluid is forced through small holes in the barrier(s) during violent impacts.

Background Art

Fluid filled impact absorbing devices have been described in a previous patent application, PCT/GB9603243 (Courtney) filed by the present inventor. The earlier patent application relates to impact absorbers comprising flexible walled packages filled with a mixture of a viscous liquid, jelly or grease and a plurality of resilient gas filled capsules, with the liquid component of the mixture filling all of the void space between the gas filled capsules. The liquid fraction was an essential part of the earlier invention but its inclusion created the following potential design problems:

1. The liquid provided some viscous damping but the viscous damping per unit mass of liquid was low compared with conventional dashpot type dampers, where the liquid is driven through a permeable barrier, by a pressure difference across the barrier.
2. The liquid component of the invention makes it heavier than expanded elastomeric foam impact absorbers of the same volume.
3. For some versions of the earlier invention it is possible that during an impact, all of the material inside the package will flow to the sides of the impact zone, allowing the front and back, inner surfaces of the package walls to come into direct contact. I.e. the device bottoms out and completely loses its cushioning ability.
4. The walls of the flexible package could catastrophically unzip during a violent impact, with the enclosed fluid being released into the local environment, causing contamination and/or creating slippery surface hazards.

The current invention improves on the invention described in PCT/GB9603243 (Courtney) by using permeable barriers to make more efficient use of the energy absorbing properties of the viscous liquid, by incorporating internal elastomeric solid or foam layers to solve bottoming out problems and by improving the packaging design, in order to solve the problem of catastrophic unzipping.

Brief description of the drawings

Figure 1 depicts a typical dynamic compressive stress-strain curve for an impact absorber, according to the earlier invention.

Figure 2 depicts the modified dynamic compressive stress-strain curve for the same impact absorber, with a permeable barrier added according to the present invention.

Figure 3 depicts an improved version of the invention which has the ability to heal itself after a violent impact.

Figure 4 depicts a plan cross section of a car bumper constructed according to the invention.

Fig 5 depicts the same bumper during an impact.

Figure 6 depicts an impact absorber which uses the viscous damping mechanism described for the car bumper but employs two sub-chambers in sequence along the line of action of the impacting force.

Figure 7 depicts a cross section of a rigid beam which includes an impact absorber according to the invention.

Figures 8 to **12** show five different designs of vibration damping devices or mounts according to the invention.

Figure 13 depicts an example of the device having a pleated protective cover, with the inner package being an impact absorbing cushion taking the shape of a slightly flattened cylinder, with elliptical cross section.

Figure 14 depicts an alternative design to that illustrated in figure 13, which overcomes the trapped pleats problem.

Figure 15 depicts an example of the device with the outer cover being constructed from an elastomeric polymer and having a corrugated cross section.

Figure 16 depicts an embodiment of a composite version the invention which includes an elastomeric base layer or pallet inside the package.

Figures 17 and **18** depict the composite version of the invention during successive stages of a violent impact.

Figure 19 depicts a composite version of the invention which can offer improved protection to the underlying surface.

Figure 20 depicts a variation of the composite version of the invention, which allows articulation of the impact absorber, even if the solid layers are made from rigid impact absorbing materials.

Disclosure of the invention

The inventive step described in this patent application is a method for increasing the viscous damping offered by known, fluid filled impact absorbers, by forcing some of the liquid through one or more permeable barriers during the impact absorption process. The patent application will also reveal a method of locally retaining the liquid which could escape through the package walls during a violent impact. A third feature of the improved version of the invention is a method for exploiting the pressure equalisation benefits of fluid filled impact absorbers, without incurring the problem of the front and back, inner surfaces of the package walls coming into direct contact during an impact. An additional benefit of the third innovative feature is that the mean density of the improved device can be reduced, compared with the earlier invention. because the fractional volume of liquid required for efficient functioning of the device can be decreased.

The present invention is an improvement on patent application PCT/GB9603243 (Courtney) but the improvements to be described may equally well be applied to any type of impact absorbing device which includes a mixture of resilient capsules and incompressible fluids. The resilient capsules for the present invention may be solid elastomers or include a trapped volume of gas. In what follows, the incompressible fraction of the fluid will be referred to as a liquid, but it is to be understood that, in general, the liquid could be replaced by a grease or jelly. The earlier patent application was also restricted to impact absorbing devices which were characterised by having at least one easily deformable face. The present patent application is not restricted to this type of impact absorber.

It is extended to include impact and vibration absorbers which are characterised by rigid loading surfaces, for example, piston and dashpot type impact absorbers.

The earlier invention offered the possibility of providing viscous damping in at least two ways:

1. The rearrangement of the liquid when closed gas capsules contracted in size during an impact provided bulk viscosity damping.
2. The shearing of liquid layers which occurred when liquid moved in or out of the open ended gas capsules, for some versions of the device, caused a shear viscous damping effect.

The present invention generates additional viscous damping to 1 and/or 2 above by driving the liquid through one or more permeable barriers which have been added to the improved device. The permeable barriers can take the form of partitions inside the device which separate the fluid contents into two or more sub-chambers, which can exist at different pressures during the impact. Alternatively, the barrier can be part of the packaging system. Both types of barrier will be described below. According to the present invention the design engineer has a choice of two types of permeable barrier:- Step function or continuous function. Step function barriers do not leak during low energy impacts. With continuous function barriers leakage through the barrier can occur at all levels of impact but the volume of leakage and the magnitude of viscous damping forces increases as the degree of violence of the impact increases.

The barrier(s) may be made permeable using several alternative methods. The following methods are by way of example only and are not intended to limit the scope of the invention:

1. Barriers may be made from a strong woven material with one surface of the fabric being coated with a sealing compound which breaks down and allows leakage through the weave at the desired pressure difference across the barrier.
2. The coated layer in the first type of barrier may be dispensed with and the woven fabric chosen such that the tightness of the weave will not allow significant leakage through the barrier, during low energy impacts.
3. Barriers may take the form of sheets of metal, wood or solid polymer material with a plurality of small holes made in the faces of their planes. Plugs or other means of sealing holes at low compressive stress differences may be added to these types of barrier, to convert them into step function barriers.
4. The porous zones may be introduced as puncture holes at the points where parts of the package are sewn together. A sealant may be added on top of the lines of sewing to create a step function which does not leak at low compressive stresses.
5. The barrier may take the form of a plurality of permeable sheets in series, optionally having different step function breakdown stresses, with each successive sheet layer allowing leakage to the next sheet layer at a higher compressive stress difference. If the sheet materials are slightly elastic then the liquid can pass trough the first sheet layer of the barrier and become trapped there until the pressure gradient is sufficiently high to force it through the second sheet layer and so forth.

The benefits of adding permeable barriers to the earlier invention can readily be understood by reference to the dynamic compressive stress-strain curve for a typical sample of the device.

Figure 1 depicts a typical dynamic compressive stress-strain curve for an impact absorber, according to the earlier invention.

Point 1 on the curve is the maximum acceptable compressive stress for a hypothetical application of the pad. It is assumed that if this stress is exceeded, then an unacceptable degree of damage will be done to the body being protected.

The work done in absorbing impact energy per unit volume of the shock absorbing device, before the maximum acceptable compressive stress is reached, is given by the area under the graph up to point 1. It is a desirable characteristic of the device that this area should be as large as possible.

Point 2 on the curve is the compressive stress level at which the proposed permeable barrier, when added to the improved device, starts to leak significantly.

Figure 2 depicts the modified dynamic compressive stress-strain curve for the same impact absorber, with a barrier added according to the present invention. In this example, the barrier could be a woven outer packaging, with the material being coated, so that it creates a step function barrier that only starts to leak at fairly high compressive stresses.

Points 1 and 2 in **Figure 2** have the same meaning as in **Figure** 1.

Work is done against viscous forces as the liquid is driven through the permeable barrier and the point of application of the external force moves forward. The work done per unit volume of impact absorber, before the compressive stress reaches an unacceptably high level can be calculated from the area under the graph up to point 1, as for figure 1. The effect of adding the permeable barrier is to increase the amount of work that can be done to absorb the impact energy, before an unacceptable level of compressive stress is reached.

In order to prevent contamination of the local environment, from the permeable packaging version of the device, following a violent impact, an elastic outer cover or bag can be added. The improved version of the device traps any leaked material between the outer cover and the permeable membrane barrier. Examples of suitable barriers will be described later in this application.

The invention may be improved by inserting one or more thick sheets of elastomeric solid or foam material inside the package, with the plains of the sheets being approximately at right angles to the direction of impact of the external, impacting body. The hydraulic pressure equalisation characteristics of the invention enable the whole of the volume of the elastomeric sheets to be compressed during the impact. These sheets are sufficiently thick that they can compress measurably during the impact, absorbing a significant fraction of the impact energy.

Further embodiments of the invention

The version of the new invention, with the inclusion of permeable walled packaging, as explained with reference to figure 2 above can be used in marketable products but it suffers from the disadvantage that the device is permanently damaged after one severe impact.

Figure 3 depicts an improved version of the invention which has the ability to heal itself after a violent impact. In **Figure 3** the impact absorbing material, 1 is enclosed in a package, 2. The magnified view which is shown on the

right of the diagram depicts the structure of the package wall in more detail. Item 3 is part of the inner layer of the wall and is a woven fabric which becomes permeable when a sufficiently high pressure difference exists across the layer. Item 4 is part of an elastic, impermeable outer membrane layer which is strongly bonded to the inner layer at intervals, in the manner of quilting. During violent impacts, liquid is driven through the barrier, 3, stretching the elastic outer membrane layer, 4 and creating liquid filled bubbles such as 5. The bubbles are created in a short period of time during the impact, typically about 0.1 seconds,. The small pressure difference caused by the local stretching of the outer layer can still drive the liquid back into the main body of the device, but the healing process takes a relatively long time. Depending on the tightness of the weave of 1, the elasticity of layer 4 and the dynamic viscosity of the liquid, recovery can take place in a matter of minutes or days.

One of the design features of impact absorbing pads made according to the earlier invention was that hydraulic fluid pressure transmitted the compressive stress equally in all directions. This meant that if the area of the impact zone was a fraction of the total front surface area of the pad, say for example 70%, then the volume of impact absorbing material under the remaining 30% of the front surface, outside the impact zone, could still play an active role in absorbing the energy of the impact. This highly efficient use of the total impact absorber volume cannot be maintained indefinitely. If the front surface area of the pad is too large, then its contents can flow to the sides of the impact zone, allowing the inner surfaces of the front and rear faces of the pad under the impact zone to make hard contact. That is, the pad will bottom out. According to the present invention, the inclusion of permeable barriers, inside the pad, can significantly reduce this problem.

Figure 4 depicts a plan cross section of a car bumper, which in this case is essentially a long, slender pad shaped version of the device. The outer surface of the bumper, 1 is the packaging material for the pad. For simplicity of explanation it will be assumed that the packing material is a totally impermeable single layer. The vertical dashed lines such as 2 and 3 represent permeable barriers which partition the fluid contents into a number of connected sub-chambers. The permeable barriers are made from a strong, flexible material which does not stretch significantly during an impact. The barriers could, for example, be permeable sheets securely anchored to the inner walls, so that they do not move along the length of the bumper, away from an impact zone. Optional, strong but flexible cross ties such as 4 may link the permeable barriers. The cross ties limit the amount of lateral bulging of the permeable barriers during impact. Alternatives to anchoring the permeable barriers to the inner walls of the bumper are to pack the elastomeric capsules into a number of adjacent bags made from strong, permeable material or to pack the elastomeric material into a long permeable, stocking like tube, with the tube being twisted through at least one hundred and eighty degrees, at intervals along its length, to create a plurality of separate, elastomeric capsule filled compartments.

Figure 5 depicts the bumper during an impact, represented symbolically by the swinging hammer. 1. The sub-chambers directly under or near the impact zone such as 2 and 3 partially collapse and are compressed in the approximate direction of the impact. The permeable barriers enclosing the collapsed sub-chambers are compressed in the line of their planes and are free to move, so that there is no pressure gradient across their faces.

Sub-chambers at a distance from the impact zone, such as items 4 and 5 in figure 5 are enclosed by permeable barriers which experience a resultant stress at right angles to their planes. For these regions of the bumper a

pressure gradient across the permeable membranes can exist.

The pressure gradients across successive permeable membranes, moving away from the impact zone gradually reduce the excess pressure in successive sub-chambers, until after a number of sub-chambers have been traversed the excess pressure is negligible. The number of sub-chambers involved in this step reduction in excess pressure depends on the dimensions of the holes in the permeable barrier and the viscosity of the liquid.

A practical effect of partitioning the impact absorbing bumper by the inclusion of permeable membranes is that, during an impact, the device creates an active volume around the impact zone. This volume participates in the impact absorbing process by providing elastic and viscous damping energy absorption but the active volume is self limiting. The device can be designed to eliminate the problem of local thinning to zero thickness and consequent bottoming out. An alternative method of solving the bottoming out problem, which is less effective in the exploitation of viscous damping, but reduces the unit weight of the device will be described later.

Figure 6 depicts an impact absorber which uses the internal, viscous damping barrier principle described for the car bumper above, but employs two sub-chambers, 1 and 2 in sequence along the line of action of the impacting force.

The two sub chambers are separated by a stiff permeable barrier, 3 which does not stretch significantly under impact. For example, 3 could be a steel plate with a plurality of small holes drilled through it. The leading sub-chamber, 1 has a flexible face, 4 which deforms to the shape of the front of the impacting body. The second sub-chamber, 2 is enclosed at its sides and at its base by a rigid walled case 5, so that it does not deform directly under impact. The contents of sub-chamber 2 are only compressed indirectly by the passage of liquid through the permeable barrier during the impact. When the external deforming force is reduced the resilient capsules such as 6 in sub-chamber 2, expand and recover, driving the excess liquid back through the barrier into sub-chamber 1. The device may take any convenient shape at right angles to that shown in the diagram. For example, Figure 6 could be a vertical cross section through a vertical cylinder or a long horizontal beam. The rigid walled case, 5 may be designed to buckle and absorb some impact energy under exceptionally violent impact conditions. The case may be hollow and filled with elastomeric foam or an elastomeric capsule and liquid mixture.

Typical examples of load bearing beams which require side cushioning include the A and B pillars which help to support the roofs of motor vehicles. Figure 7 depicts a cross section of a rigid beam, 1 at right angles to its length. The device has a flexible front face 2, a front sub-chamber, 3 and a rear sub-chamber, 4. Item 5 is a second hollow beam, also shown in cross section, which reinforces the first hollow beam, 1. Hollow beam 5 also doubles as the permeable barrier because a plurality of small holes, such as 6 are drilled through its front side as shown in the diagram. In addition to making very effective use of the available space, the elastomeric fluid inside the secondary beam 5 in this design, can also help to reinforce the beam, 5. In the event of a severe impact on the beam at right angles to its length which causes 5 to compress telescopically and buckle in folds, the compressible fluid inside the beam would help to even out the forces and encourage many small energy absorbing folds to be created instead of a small number of large ones.

Figure 8 is a vibration damping device or mount which is essentially the same in construction as the impact absorber illustrated in figure 6. In Figure 8 a piston, 1 transmits the force of the vibration to the front sub-chamber 2 and then indirectly to the rear sub-chamber, 3 through the permeable barrier, 4. The side walls of the front sub-chamber take the form of a collapsible bellows, 5. A helical coil spring, 6 is optionally added to increase the elastic stiffness of the mount. On the down stroke of the piston, the elastic cells in the front sub-chamber are compressed and some of the liquid is driven through the permeable barrier, compressing the elastic cells in sub-chamber 3. The movement of the liquid through the permeable barrier provides viscous damping. The fraction of the impact energy which is elastically stored in the compressed cells and helical spring restores the device to its original length after the impact force has diminished. During recovery, the negative pressure change in the front sub-chamber 2 and the expansion of the cells in the rear sub-chamber 3 to their relaxed size, pumps liquid back out of rear sub-chamber and into the front sub-chamber.

The energy damping process heats up the liquid. This heat can be efficiently dissipated through the solid case 7 if it is constructed from thermally conducting material. If necessary, cooling fins can be added. (Fins not illustrated.)

A desirable feature of many vibration dampers is that they provide different degrees of damping on the down stroke and the return stroke. This feature can be incorporated into the present invention by allowing the permeable barrier to take the form of a rigid permeable sheet which can move up or down in the manner of a valve. Figure 9 depicts a vibration damper which incorporates differential damping. The permeable barrier, 1 rests on a helical spring, 2 which in turn rests on an inner ledge, 3. Permeable barrier 1 has a smaller diameter than the interior diameter of the second sub-chamber 4, so when the helical spring, which supports 1 is relaxed, a gap exists between barrier 1 and the adjacent side wall. On the down stroke, the internal helical spring is compressed, closing the side gap and forcing the liquid to pass through the small holes in barrier 1. On the up stroke the peripheral gap opens up and the liquid can take the easy return path through the gap.

If the peripheral gap is sufficiently large that there is a danger of gas capsules becoming trapped in the gap then the capsules may be retained by open mesh barriers, with the mesh size being smaller than the capsules in their compressed state but sufficiently large that the mesh only plays a secondary damping role, compared with the primary permeable barrier, 1.

The valve arrangement, as illustrated in figure 9 could be applied to the impact absorber illustrated in figure 6. This type of impact absorber could be for example be used as a heel or sole cushion in an orthopaedic or sports shoe. The design would offer a high level of impact protection for sports such as basketball without sacrificing the desirable characteristic of a springy shoe which aids repeated high jumping and efficient running. For shoe designs the inventive features could take a different embodiment. For example, the helical spring could be replaced by a plurality of small elastomeric blocks or the permeable barrier could be shaped so that its perimeter also acted as a spring. The permeable barrier could have a two layer construction with the two layers having a small vertical separation. Large apertures in the two layers could be offset so that when compressed together, the effective size of the holes available for liquid transmission through the barrier was significantly reduced.

The mounts illustrated in figures 8 and 9 can be tuned at the manufacturing stage in a number of different ways, in order to optimise their performance.
The elastic stiffness of the mounts can be altered by changing the fractional volumes of gas filled capsules in the sub-chambers or by altering the stiffness of the optional external helical spring.
The damping can be altered by changing the viscosity of the liquid, the degree of permeability of the permeable barrier or by changing the compressible volumes on either side of the barrier. The compressible volume in the upper sub-chamber can take any value between zero, if it contains no resilient capsules and a maximum which is equal to the total compressible volume of the resilient capsules when they are close packed.
The damping characteristics of the mounts can also be tuned after they have been assembled, if the total volume in the lower sub-chamber can be altered. **Figure 10** depicts a design which permits on-site damping adjustment. The mount in this figure is similar to that illustrated in figure 9, but it also incorporates a wide diameter bolt, 1 which acts as a piston. By tightening up the bolt the volume in the lower chamber is reduced.

Figure 11 depicts a mount which permits on-site elastic stiffness adjustment. This is similar to the mount shown in figure 10 but has an external, air tight bellows, 1 which can be filled to a high pressure with air or a mixture of liquid and air through a valve 2.

The vibration absorbing mounts described in this patent application can be converted into "smart" mounts by including electric circuits which can be employed to change one or more characteristics of the mount in response to changes in the external, vibration inducing environment. Three possible designs will now be described in sufficient detail for a competent engineer to construct them.

Figure 12 depicts a mount similar that shown in figure 10, except that the piston, 1 is a sliding fit. The piston moves in response to a force impressed upon it by a linear motor, 2. Engineers with a knowledge of electronic control systems will be capable of coupling this design of mount to vibration or road terrain sensors in order to create a "smart" vibration damping system.

A second possible "smart" mount design based on the current invention uses coaxial Piezo-electric fibres to form the permeable barrier, with the size of the gaps in the mesh being altered when the diameter of the fibres is altered by the application of a potential difference across the coaxial conductors built into the fibres.

The third "smart" design exploits the valve action of the permeable barrier, 1 shown in **Figure 9**. The position of this valve, and hence the degree of viscous damping, could be controlled by electromagnets. For example, by the addition of magnetically interacting, current carrying coils to the perimeter of the valve and the adjacent inner ledge, 3.

Leak-proof versions of the device were described earlier and illustrated in figure 3. A lower cost, leak- proof version, for single impact applications will now be described. This version has two layers of packaging, an inner package that is stout enough to withstand moderate impacts and an outer cover that acts as a fluid capturing

reservoir, if the inner layer leaks. The outer cover is designed so that under impact conditions it can increase in volume to store all of the fluid ejected from the inner package following leakage or a rupture. The outer cover can in principle be any large, loose, sealed bag encompassing the inner package. However for eye appeal or functional reasons this is unlikely to be acceptable for many applications. A number of more practical designs for the outer cover or bag will be described by way of example but they should not be considered as in any way limiting the scope of this feature of the invention.

If the outer cover is a large bag, it can be tailored to fit neatly over the inner package by using folded gussets or pleats to take in the slack material. **Figure 13** depicts an example of the device according to this version of the invention, with the inner package being an impact absorbing cushion taking the shape of a slightly flattened cylinder. Item 1 is the flexible inner package retaining a blend consisting of a viscous liquid, 2 and elastic walled gas filled capsules such as 3. Item 4 is the outer cover which is tailored to fit neatly over item 1 but for clarity of illustration is shown slightly larger than item 1.

The outer cover may be made from any flexible material which is capable of retaining the ejected fluid. Suitable materials for the outer cover include non woven materials such as polythene sheeting or tightly woven fabrics such as Pertex ® or Ventile ®.

The woven materials may be sealed or proofed to prevent the slow seepage of fluid from the device following a rupture but tightly woven materials which are not sealed are adequate for eliminating the problem of widespread contamination by ejected fluid following a violent impact.

An advantage of selecting an unsealed micro-fibre material such as Pertex for the outer cover is that it can be used to wick away perspiration if the pad is designed for use in prolonged close contact with the human body.

5 and 6 are examples of pleats in the outer cover which can unfold and expand to retain leaked fluid if the inner package bursts. The pleats can be lightly fixed in place by using tacking stitches, staples, weakly bonding adhesives, adhesive tape, spot welds, touch and close material or other means of lightly securing them.

The design of outer cover shown in **Figure 13** will not work efficiently if the impacting force is spread over the whole of the upper face of the device and traps the pleated material against the inner package.

Figure 14 depicts an alternative design which overcomes the trapped pleats problem. In **Figure 14** the outer cover, 1 has external pleats such as 2. If there is any danger of the pleated material being partially trapped by the external forces then the unfolding of the pleats may be assisted by lubricating the pleated material or separating the layers of the pleats using thin sheets of low friction material such as PTFE.

An alternative to the use of pleats is to construct the outer cover from a highly elastic material. In this version of the invention the outer cover can be a contact fit over the whole of the inner package when in normal use but can expand to accept the ejected fluid following a rupture of the inner package. Materials scientists will be aware of the elastomeric polymers suitable for this application. An alternative to a non woven elastomeric polymer based outer cover is to construct the outer cover from a highly elastic close woven material such as Lycra ®.

Whatever design or type of material is used for the outer cover, the volume of the outer cover should be able to increase sufficiently so that the cover can enclose any liquid ejected from the inner package, even when the inner package is completely flattened and all of the liquid is driven into the outer cover.

In addition to fulfilling its essential role of retaining any leaked fluid, the outer cover may also perform other duties. **Figure 15** depicts a device with the outer cover, **1** being constructed from an elastomeric polymer and having a corrugated cross section. If a device having this design was used for example as a back rest in a vehicle seat, the corrugations would provide air flow channels which would ventilate the cushion and keep the users back cool. A suitably selected material could be used for the outer cover which was sufficiently rigid that it provided a massaging effect when subjected to low compressive stresses but flexed under impact conditions, to allow the full potential of the underlying impact absorber to be utilised. The corrugated sections could be replaced by a plurality of local protrusions, in the outer cover, to produce a similar ventilating or massaging effect.

The elastic outer cover may become scuffed or punctured during its working life. Engineers will be aware of a number of methods of constructing self repairing outer covers including the use of healing polymers which re-bond together after being scratched or including a fluid in the space between the inner and outer bags which cures on exposure to air to seal the puncture hole, following an accidental puncturing of the outer cover. The outer cover may be designed to provide visual evidence that it has been damaged. For example, it may be constructed from a two layer laminate with the layers having contrasting colours which highlight any thinning due to abrasion. Alternatively, it may be preferable to construct the outer cover from a transparent material such as polythene to allow visual inspection of the inner package. In the latter case the inner package may be made from a two layer contrasting colour laminate to aid damage inspection.

Selected chemicals may be added to the space between the inner and outer walls to confer a number of benefits. The chemicals may be chosen, for example, to react with the fluid leaking from the inner package following a puncture of both layers of packaging, to solidify the fluid, to ease the cleaning up process after a major impact incident. Alternatively the chemicals may react with the fluid from the inner bag, to create a foam, inside the outer cover, which acts as a second defence cushion, to provide partial protection against further impacts. If the impact absorbing cushion is used for marine applications the chemicals may be chosen to react to generate a gas which inflates the outer cover to create a buoyancy aid. Other possibilities include, the generation of foams or gases, which are used to suppress combustion following an accident.

Electrodes may be placed between the inner and outer walls or attached to them, which complete a circuit if the inner wall is ruptured with internal leakage of fluid. The completed circuit may be used to initiate a number of actions including the triggering of remote alarms. If the cushion takes the form of a bumper on a vehicle the action initiated could be the inflation of passenger or pedestrian protection air bags. For airborne applications, the action initiated could be the deployment of parachutes.

A sheet of thermosetting plastic, foam, plywood or other material may be interposed between the inner and outer walls on one face of the device to give it a preferred shape.

One of the design features of impact absorbing pads made according to the earlier invention, revealed in patent application PCT/GB9603243 (Courtney), was that hydraulic fluid pressure transmitted the compressive stress equally in all directions. This meant that if the area of the impact zone was a fraction of the total front surface area of the pad, say for example 70%, then the volume of impact absorbing material under the remaining 30%, outside the impact zone, could still play an active role in absorbing the energy of the impact. This highly efficient use of the total impact absorber volume cannot be maintained indefinitely. If the pad is too large then its contents can flow to the sides of the impact zone, allowing the inner surfaces of the front and rear faces of the pad under the impact zone to make hard contact. That is, the pad will bottom out and lose its cushioning ability. A solution to the bottoming out problem has already been described above. This involves the incorporation of permeable barriers inside the package and is depicted in figures 4 and 5.

Figure 16 depicts an alternative embodiment of the invention which overcomes the bottoming out problem and may be used with or without the internal permeable barriers. This embodiment also reduces the relative volume of incompressible fluid required for efficient operation of the device. In figure 16, item 1 is a base layer or pallet with optional side walls, 2. The base layer is typically constructed from closed cell, elastomeric foam, for example, expanded polystyrene or expanded polypropylene foam. Alternatively, the base layer may be constructed from a solid, elastomeric polymer or other elastic solid. Item 3 is the upper layer, comprising a mixture of resilient capsules and an (effectively) incompressible liquid. The circles, for example 5, depict the resilient capsules. The whole of the void space between the capsules is assumed to be occupied by the liquid. Item 4 is the outer packaging which totally encloses layers 1 and 2. The package walls are constructed from flexible, high tensile stiffness material. The walls deform easily but do not stretch significantly during an impact. They can be made permeable using any of the methods described earlier. If necessary, the packaging material can be bonded to the external surfaces of the base layer, to prevent liquid leaking round the sides of the base, inside the walls. For ease of assembly, it may be desirable for the elastic fluid to be pre-packaged in one or more separate, flexible sachets. However, such sachets are not a substitute for external packaging that encloses all of the fluid and solid sheet layers. The dynamic equilibrium of forces during an impact, created by the reaction forces exerted on the external package walls by the fluid and solid layers is essential for the correct hydraulic functioning of this version of the invention.

Figures 17 and 18 depict the composite version of the invention at successive stages of absorbing a violent impact. In figures 17 and 18, item 1 is an impacting body, which could for example be a solid sphere which has been dropped, from a height, onto the horizontal impact absorber. In both diagrams the impact absorber rests on a very stiff, flat, solid surface, 2 which does not absorb a significant fraction of the impact energy.

At the early stage of the impact depicted in figure 17 the upper surface of the package wall has deformed but has not yet distorted sufficiently that it makes contact with the upper surface of the lower, solid layer. The resilient

capsules decrease in volume during the impact but the volume of the liquid remains effectively constant. Consequently, the fractional volume of the capsules decreases compared with the liquid volume, the capsules move out of close contact and are free to rearrange themselves to accommodate the change in the shape of the package. The liquid exerts hydraulic pressure which acts at right angles to any adjacent solid surfaces. The arrows, e.g., 3 in **figures 17** and **18** indicate the directions of the resultant liquid pressure at some of the solid surfaces. The hydraulic pressure is exerted on all of the surfaces of the pallet which are in contact with the liquid. As a result, pallet material to the sides of the impact zone can participate in absorbing impact energy.

Figure 18 depicts a later stage of the impact, when the pallet material is crushed directly. The pallet material, 4 under the impact zone now acts as a conventional solid or foam impact absorbing material but because of the hydraulic pressure equalisation phenomenon the resilient capsules and pallet material such as 5, to the sides of the impact zone, continue to experience an increasing compressive stress and continue to absorb impact energy.

The shapes of the cross sections of the layers depicted in **figure 16** are not to be understood as limiting the invention. Depending on specific design requirements, the thickness or surface shape of the layers may vary across the profile and the local density of the solid material may vary. The interior surfaces of the solid base, in contact with the liquid may take up any range of shapes preferred by the designer, in order to increase the surface area of the solid material in contact with the liquid. The invention may consist of a plurality of alternating layers of fluid and solid materials. A plurality of adjacent solid compartments such as item 1 with side walls, 2 in **figure 16** may be housed within a single outer package. The solid layers may be cut into segments and bonded to a flexible base, in order to allow articulation of the impact absorber, while maintaining high compressive stiffness. Some of these variations will now be described in greater detail.

An important feature of the impact absorber depicted in **figures 16, 17** and **18** is that the redistribution of the resilient capsules during the compression process helps to distribute the reactive stresses on the impacting body, 1 more uniformly than if the same body had collided with a solid impact absorber having the same stiffness as the mean stiffness of the resilient capsules and the pallet material.

The same reactive stress redistribution benefits can be offered to the underlying surface, using a variation of the invention as depicted in **figure 19**. In **figure 19**, in additional to the upper layer, 1 a lower layer 2, also consisting of resilient capsules and (effectively) incompressible liquid has been added. The composition of layers 1 and 2 may differ. For example, if the impact absorber is being used as part of the shell material of a prefabricated hospital, for use in low temperature war zones, the liquid in the outer layer could be an organic liquid with a low freezing point and the liquid for the inner layer could be water based, in order to provide a high latent heat of vaporisation, to absorb thermal energy, in the event of a fire or explosion inside the building. On a smaller scale, the liquid fractions could have different thermal conductivity's, so that if the pad took the form of a seat cushion or mattress the user could select a warm or cool side for lying or sitting on.

The version of the invention depicted in **figure 20** is a variation on that depicted in **figure 19**, which allows articulation of the impact absorber, even if the solid layers are rigid under normal working, non-impact conditions. In **figure 20**, the solid material is separated into two stacked layers, 1 and 2. A plurality of wedge shaped grooves such as 3 and 4 are cut into each layer, to separate them into segments. The dissected solid blocks are then bonded to a strong, thin flexible sheet 5, to prevent them drifting around inside the package.

The novel improvements described in this patent application are capable of being applied to a wide range of designs of impact and vibration absorbers including those described by the present inventor in patent application PCT/GB9603243 (Courtney). The scope of the present invention is extended to include at least:

i) Devices based on packages, which include fluids, which have been made more compressible by including a plurality of resilient solid or flexible walled, gas filled capsules.

ii) Devices as above, in which the capsules are hollow resilient spheres.

iii) Devices as above in which some at least of the gas capsules, have at least one open end, with the gas trapped inside being retained at the boundary with the surrounding liquid by capillary action.

iv) Devices as above with the package being shaped such that it decreases in volume when being subjected to an impact.

v) Devices as above, which are partitioned, with clips or other items, which allow the relative sizes of the partitioned parts to be adjusted by the end user.

vi) Devices as above, which use flexible cross ties or spot welds to link together opposite faces of the package, to minimise the degree of local bulging, when impact forces act on a fractional part of the front face of the device.

vii) Devices as above, in which some at least, of the gas filled capsules are bonded to the inner walls of the package.

viii) Devices as above, in which, some at least, of the gas filled capsules, are linked together on internal sheets, on open mesh grids of flexible material or on long stands of fibre.

ix) Devices as above, in which, some at least, of the gas filled capsules can have their internal pressure controlled by means of connections to external valves and compressed gas supplies, such as gas compression pumps.

x) Devices as above, but having a nested structure, with larger elastomeric capsules including one or more elastomeric capsules and optionally, incompressible fluid.

xi) Devices as above, which are used as impact absorbing pads added to personal protective bodywear or body armour.

xii) Devices as (i) to (x) above, which are used as impact absorbing pads added to vehicles, to protect the occupants or objects travelling within the vehicle or persons, animals or objects outside the vehicle, during a collision.

xiii) Devices as (i) to (x) above, which are used as protective packaging.

xiv) Devices as (i) to (x) above, which are used as saddles or protective pads for animals.

xv) Devices as (i) to (x) above, which are used as road humps, sleeping policemen or other vehicle retarding means.

xvi) Devices as (i) to (x) above, in which the liquid fraction is a liquid being stored or transported with the inner package acting as the storage container.

xvii) Devices in which the fluid is an electrorheological or magnetorheological fluid, with the device being connected to suitable circuits, to activate the electrorheological or magnetorheological phenomenon in response to changing external conditions.

Claims

1. An impact or vibration absorbing device, consisting of a deformable container or flexible package, filled with a mixture of a liquid, grease or jelly fluid and a plurality of resilient capsules, with the device including one or more permeable barriers, characterised by the provision of viscous damping when some of the fluid is forced through small holes in the barrier(s) during violent impacts.

2. An impact or vibration absorbing device according to claim 1 with at least one permeable barrier being part of the external packaging or container walls.

3. An impact or vibration absorbing device according to claim 2, with the permeable barrier being covered by an impermeable elastic membrane, which is bonded to the outer surface of the permeable barrier at regular, close intervals, so that fluid which is driven through the permeable barrier during the impact is trapped locally in bubbles formed from the stretched elastic membrane, with the compressive stress generated by the stretching of the elastic membrane driving the fluid back through the permeable barrier after the impact.

4. An impact or vibration absorbing device according to any of the above claims, with at least one permeable barrier being a partition inside the deformable container or package, which creates a plurality of sub-chambers, each enclosing fluid, with the permeable barriers being approximately perpendicular to the impact absorbing face of the device.

5. An impact or vibration absorbing device according to claim 4, with the permeable barriers being sufficiently close to each other that when absorbing impacts, some of the elastomeric capsules are always trapped under the impact zone.

6. An impact or vibration absorbing device according to any of the above claims, with the interior of the device being partitioned into two sub-chambers separated by a permeable barrier and sequentially aligned along the line of action of the impact force, with the containment for the first sub-chamber having flexible sides, allowing its volume to reduce under impact and the second sub-chamber being retained by a rigid walled external containment so that its volume remains constant, but with fluid being able to flow through the permeable barrier during an impact, as the volume of resilient material in the second sub-chamber decreases and with the added fluid being pumped back into the first sub-chamber, as the resilient capsules expand after the deforming force has diminished from its maximum value.

7. An impact or vibration absorbing device according to claim 6, with the rigid container for the second volume and/or the permeable barrier being structural beams with the device providing cushioning to the side of the beam.

8. An impact or vibration absorbing device according to claim 6 or 7 with the resilience of the first volume being enhanced by the addition of elastomeric material or springs to the flexible side walls.

9. An impact or vibration absorbing device according to claims 6, 7, or 8 with the permeable barrier being a rigid spring loaded plate which acts as a valve, allowing easy flow of pumped fluid through the open valve aperture on one stroke and damped flow through the permeable material of the valve on the opposite stroke.

10. An impact or vibration absorbing device according to claim 9 with the amount of opening of the valve aperture being controlled by magnetic forces, generated in part, at least, by electromagnets activated by signals from electronic sensing circuits which monitor the external vibration inducing environment.

11. An impact or vibration absorbing device according to claims 6, 8, 9 or 10, with the rigid external container having means of volume control such as pistons or wide diameter, parallel sided screws which move the base of the container up or down relative to the position of the permeable barrier.

12. An impact or vibration absorbing device according to claim 11 with the means of volume adjustment being attached to feedback circuits which monitor the external, vibration inducing environment.

13. An impact or vibration absorbing device according to claims 6, 8, 9, 10, 11 or 12 with the porosity of the permeable barrier being controlled by the passage of electric currents through parts of the membrane or the application of potential differences across parts of the membrane.

14. An impact or vibration absorbing device according to any of the above claims enclosed by a outer flexible walled cover with the outer cover being capable of capturing and storing the fluid from within the first inner package if the inner package ruptures and loses all or at least a substantial fraction of its enclosed fluid.

15. An impact or vibration absorbing device according to claim 14 with the outer cover being a closed bag of woven or non woven material.

16. An impact or vibration absorbing device according to claim 15 with the outer cover being a bag having its exposed surface area reduced when not being used to store ejected fluid, by folding the excess material into closed pleats or folded gussets.

17. An impact or vibration absorbing device according to claim 15 or 16 with the excess outer cover material, when it is not being used to store ejected fluid, being gathered up and held lightly in place by means of tacking stitches, spot welds, adhesives or other means of bonding with the retaining bonds being sufficiently weak that they are broken by the external forces under conditions which cause the inner package to rupture.

18. An impact or vibration absorbing device according to claim 14 with the outer cover being constructed from woven or non woven material which is elastic and stretches to capture and store the fluid from the first inner package if the inner package ruptures and loses all or at least a substantial fraction of its enclosed fluid.

19. An impact or vibration absorbing device according to any of claims 14 to 18 with the outer cover having corrugations or local protrusions which help to provide ventilation and/or physical stimulation to the part of the body in contact with the device if the device is used as a cushion in prolonged contact with the human body.

20. An impact or vibration absorbing device according to any of claims 14 to 19, with the outer cover being lubricated by liquid or solid lubricants which assist it to unfold or change shape, to accommodate the fluid ejected, if the inner package bursts.

21. An impact or vibration absorbing device according to any of claims 14 to 20, with the space between the inner and outer walls storing a chemical or mixture of chemicals which can react with leaked fluid following a rupture of the inner package to solidify the fluid.

22. An impact or vibration absorbing device according to any of claims 14 to 20, with the space between the inner and outer walls storing a chemical or mixture of chemicals which can react with leaked fluid following a rupture of the inner package to create a foam which acts as a cushion to provide a degree of protection against further impacts or vibrations.

23. An impact or vibration absorbing device according to any of claims 14 to 20, with the space between the inner and outer walls storing a chemical or mixture of chemicals which can react with leaked fluid following a rupture of the inner package to create a gas or foam which inflates the outer cover sufficiently to act as a buoyancy aid if the device is used for marine applications.

24. An impact or vibration absorbing device according to any of claims 14 to 20, with the space between the inner and outer walls storing a chemical or mixture of chemicals which can react with leaked fluid following a rupture of the inner package. to create a foam or gas which has a fire inhibiting effect.

25. An impact or vibration absorbing device according to any of claims 14 to 24 including at least two electrodes in the space between the inner and outer walls which make electrical contact if fluid leaks into the space between the walls allowing the completion of an electric circuit, with the circuit initiating a secondary action such as the triggering of an alarm signal, inflation of air bags or deployment of a parachute.

26. An impact or vibration absorbing device according to any of claims 14 to 25, with the inner and/or outer walls being constructed from laminated material having two contrasting colours, with the innermost material of the laminate exposing itself for visual inspection if the outer layer of the laminate becomes damaged.

27. An impact or vibration absorbing device according to any of claims 14 to 26 with the space between the inner and outer walls including a chemical or blend of chemicals which can cure on exposure to air and which are used to automatically seal accidental punctures in the outer cover.

28. An impact or vibration absorbing device according to any of claims 14 to 26 with the space between the inner and outer walls including a solid or foam material which is pre moulded or can be moulded by the end user to give the device a preferred shape.

29. An impact or vibration absorbing device according to any of claims 18 to 28, with the device including a means of altering the gas pressure in the space between the inner and outer walls for the purpose of altering the elastic stiffness of the device.

30. An impact or vibration absorbing device according to any of the above claims, with an inner package which includes a fluid which has been made more compressible by including a plurality of flexible walled, gas filled capsules.

31. An impact or vibration absorbing device according to any of the above claims in which the gas filled capsules are hollow resilient spheres.

32. An impact or vibration absorbing device according to any of the above claims in which some at least of the gas capsules have at least one open end with the gas trapped inside being retained at the boundary with the surrounding liquid by capillary action.

33. An impact or vibration absorbing device according to any of the above claims, with the inner package being shaped such that it decreases in volume when being subjected to an impact.

34. An impact or vibration absorbing device according to any of the above claims, with the inner package being partitioned with clips or other items which allow the relative sizes of the partitioned parts to be adjusted by the end user.

35. An impact or vibration absorbing device according to any of the above claims which has flexible cross ties or spot welds to link together opposite faces of the inner package to minimise the degree of local bulging when compressive forces act on a fractional part of the front face of the device.

36. An impact or vibration absorbing device according to any of the above claims in which some at least of the gas filled capsules are bonded to the inner walls of the inner package.

37. An impact or vibration absorbing device according to any of the above claims in which some at least of the gas filled capsules are linked together on internal sheets, on open mesh grids of flexible material or on long stands of fibre.

38. An impact or vibration absorbing device according to any of the above claims which is used as an impact absorbing pad added to bodywear or body armour.

39. An impact or vibration absorbing device according to any of claims 1 to 37 which is used as an impact absorbing pad added to a vehicle, to protect the occupants or objects travelling within the vehicle or persons, animals or objects outside the vehicle, during a collision.

40. An impact or vibration absorbing device according to any of claims 1 to 37 which is used as part of a protective package.

41. An impact or vibration absorbing device according to any of claims 1 to 37 which is used as a saddle or protective pad for an animal.

42. An impact or vibration absorbing device according to any of claims 1 to 37, which is used as a road hump, sleeping policeman or other vehicle retarding means.

43. An impact or vibration absorbing device according to any of claims 1 to 37 in which the liquid fraction is a liquid being stored or transported with the inner package acting as the storage container.

44. An impact or vibration absorbing device according to any of the above claims in which the fluid is an electrorheological or magnetorheological fluid, with the device being connected to suitable circuits to activate the electrorheological or magnetorheological phenomenon in response to changing external conditions.

45. An impact or vibration absorbing device according to any of the above claims but having a nested structure. with a secondary impact absorber enclosing a plurality of inner devices according to the invention.

46. An impact or vibration absorbing device according to any of the above claims, with the package enclosing a plurality of alternating elastomeric foam or solid sheet layers and mixed resilient capsule and fluid layers.

47. An impact or vibration absorbing device according to claim 46 with the sheet layers having side walls of elastomeric material, such that the hydraulic pressure exerted by the fluid during an impact causes the walls to be compressed, absorbing a fraction of the impact energy.

48. An impact or vibration absorbing device according to claims 46 or 47, with the solid layers having internal walls, which extend into the liquid layers, to restrict lateral movement of the fluid during an impact.

49. An impact or vibration absorbing device according to claims 46, 47 or 48, with the sheet layers being dissected into small segments and mounted on a flexible base material, in order to allow articulation of the impact absorber. even if the elastomeric sheet material exhibits high compressive stiffness.

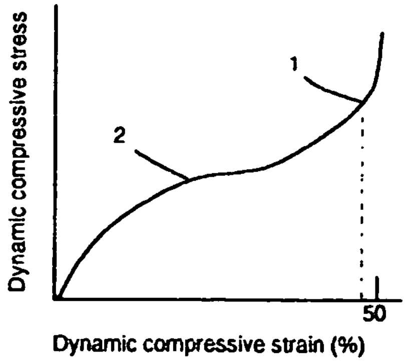

Fig 1

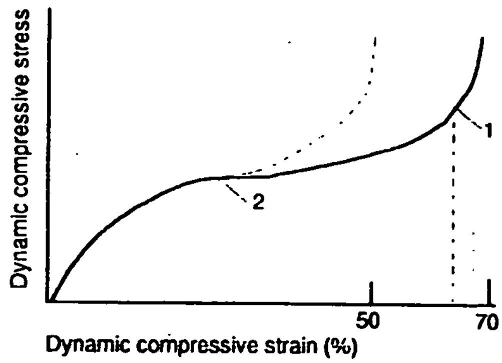

Fig 2

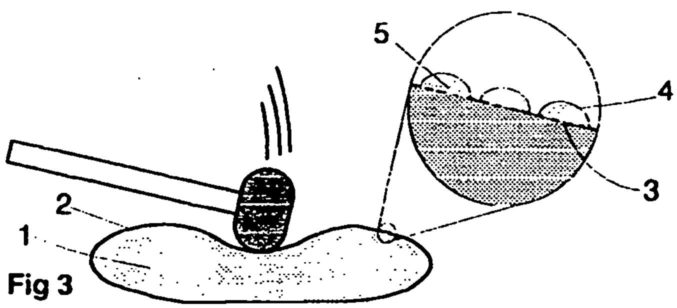

Fig 3

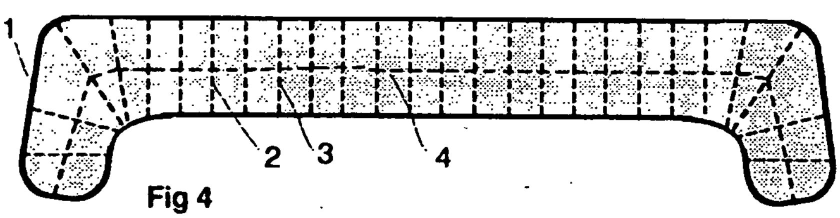

Fig 4

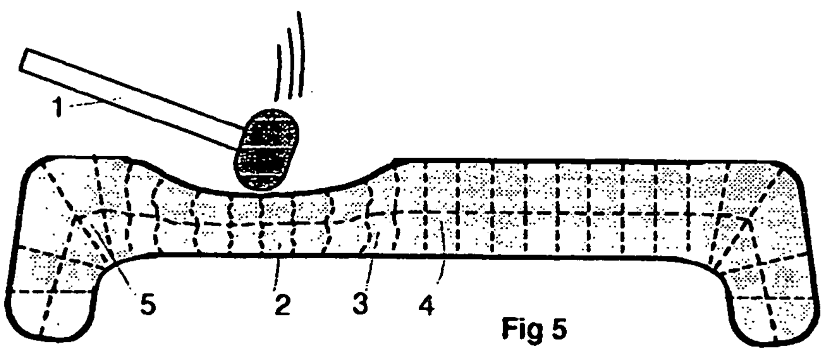

Fig 5

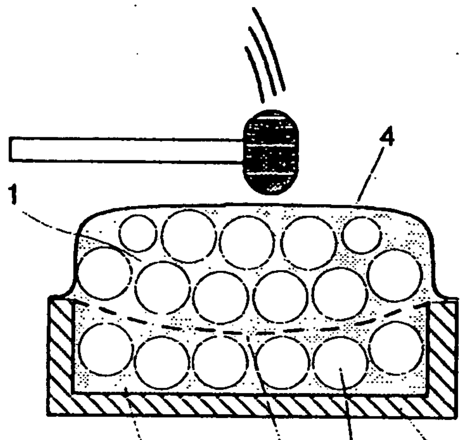

Fig 6

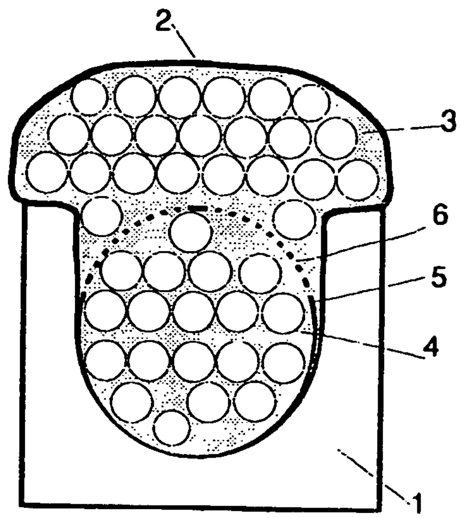

Fig 7

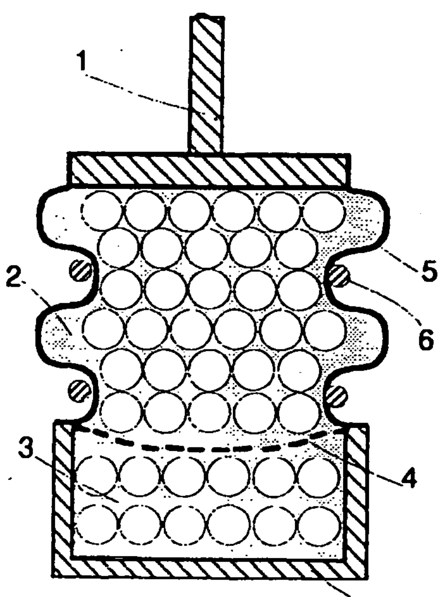

Fig 8

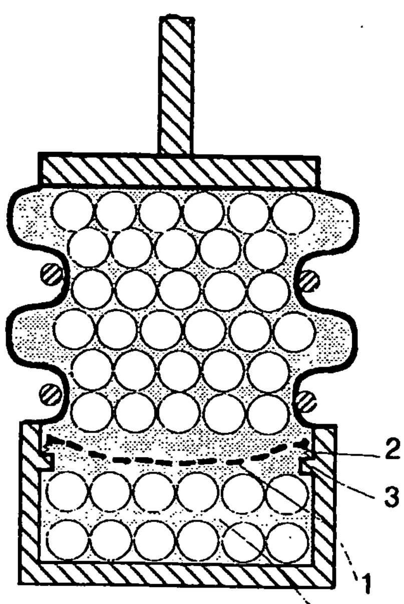

Fig 9

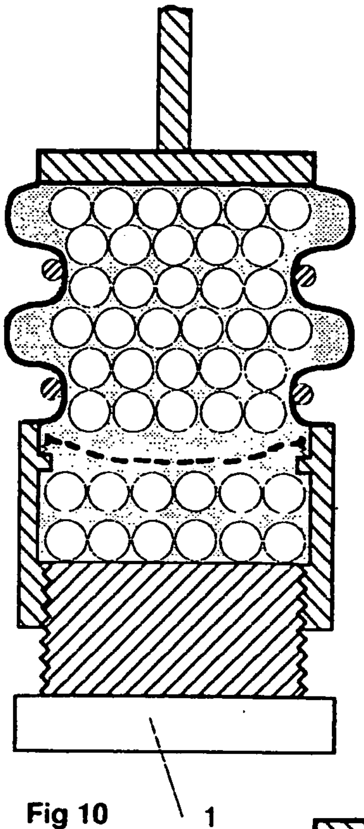

Fig 10

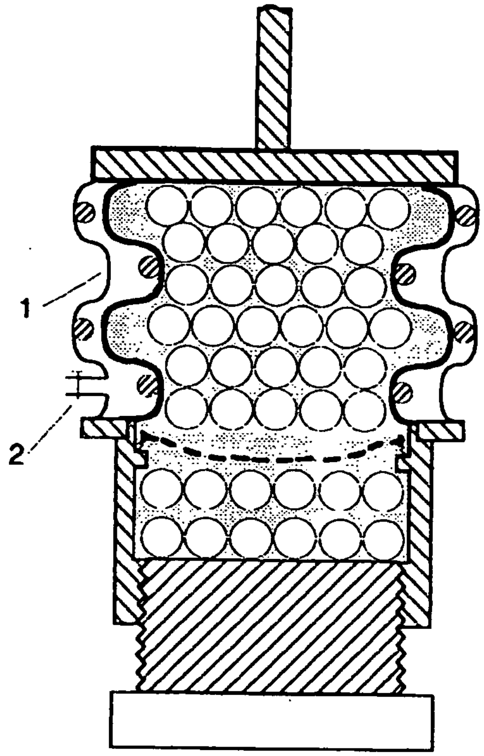

Fig 11

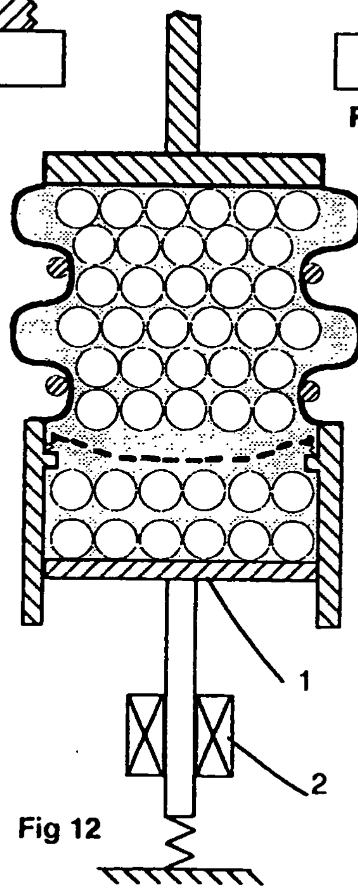

Fig 12

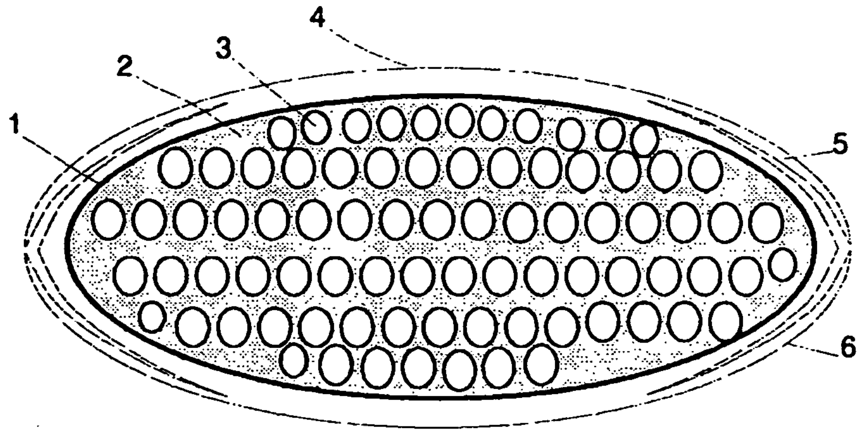

Fig 13

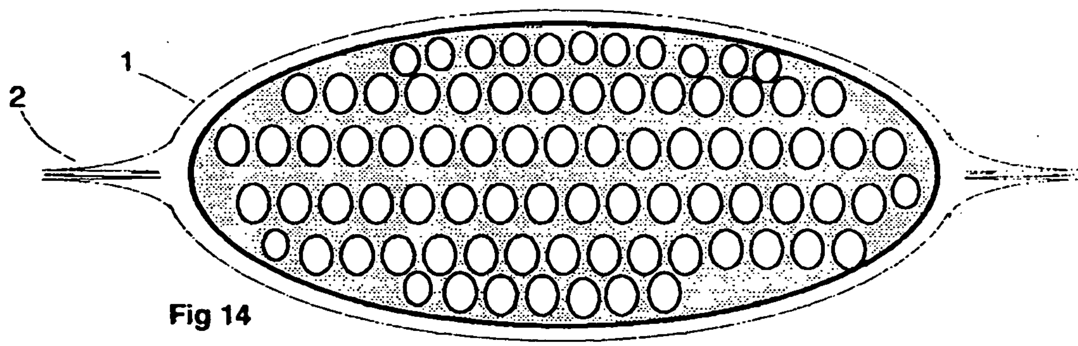

Fig 14

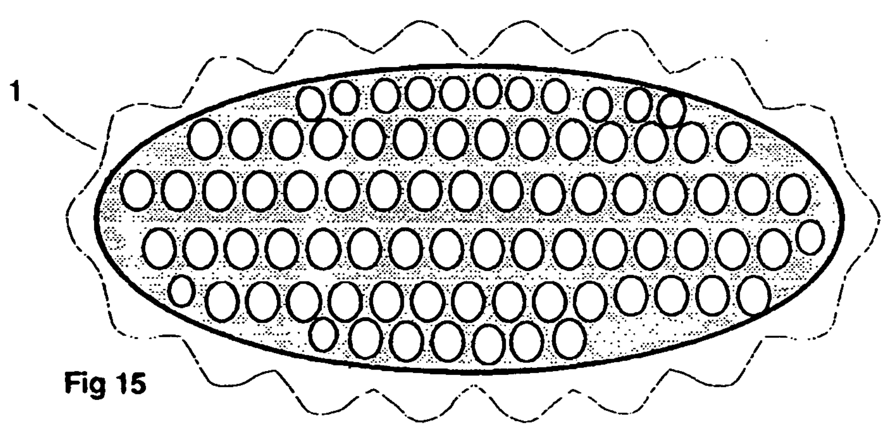

Fig 15

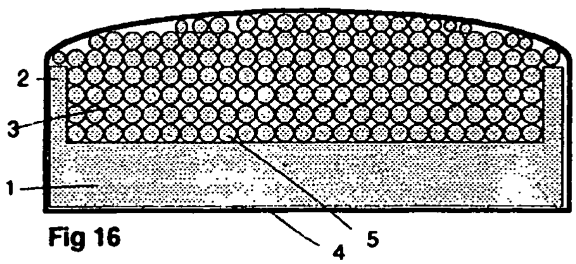

Fig 16

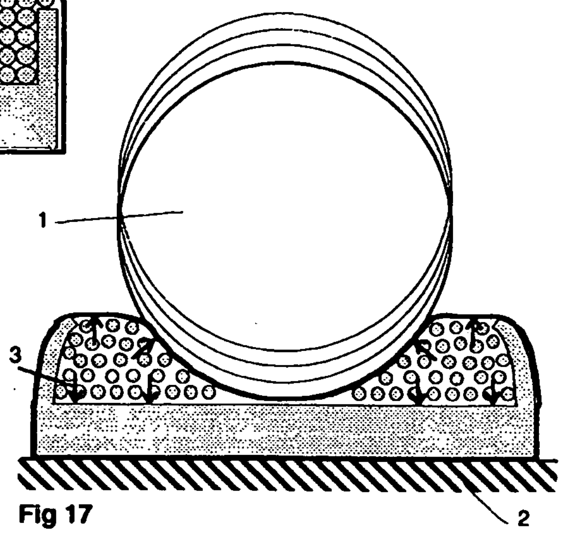

Fig 17

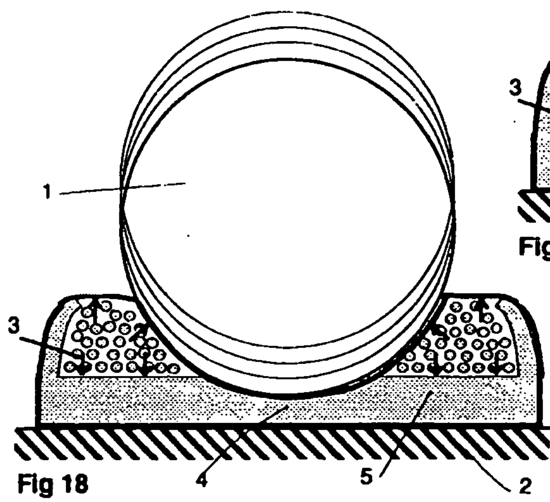

Fig 18

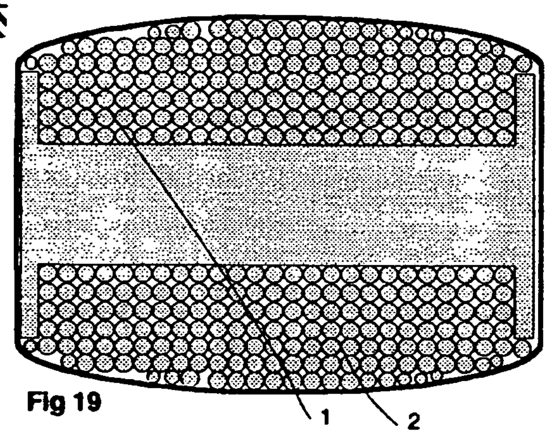

Fig 19

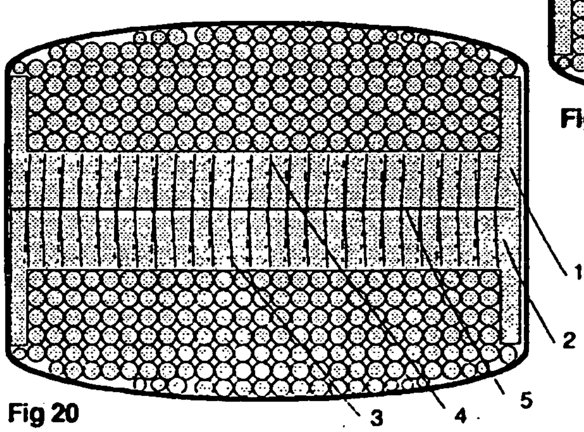

Fig 20

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 98/03594

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 F16F5/00 F16F9/00 F16F9/30 A62C3/00 A41D13/00 A43B7/32 B60K15/00 B60R21/00 A62B35/00 B64D25/00 D06F37/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 F16F A62C A41D A43B B60K B60R A62B B64D D06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 97 25551 A (COURTNEY WILLIAM ALEXANDER) 17 July 1997 cited in the application see page 4, paragraph 4 - page 19, paragraph 1; claims; figures	1,31-33, 38-41, 43-49
A		2,4,6, 14,34-37
X	US 4 566 565 A (WICKE BRIAN G) 28 January 1986 see column 4, line 18 - column 6, line 5; figures	1,30,31, 33
X	US 4 751 757 A (MORENO CARLOS) 21 June 1988 see column 2, line 24 - column 4, line 19; figures	1
A		4,6

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
16 March 1999	22/03/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Van der Veen, F

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 647 258 A (MASSARSCH KARL R) 3 March 1987 see the whole document	1
A		30,36,37
A	US 5 564 202 A (HOPPENSTEIN REUBEN) 15 October 1996 see the whole document	1,2, 36-38
A	DE 27 01 181 A (PICKER) 20 July 1978 see page 2, paragraph 3 - page 5, paragraph 3; figures	1,6, 30-34
A	WO 97 16084 A (WELSH NICOLE) 9 May 1997 see abstract; claims; figures	1,4,6, 14,38,41
A	US 5 190 248 A (LEE PETER R) 2 March 1993 see the whole document	1,4,6
A	FR 2 738 998 A (AFFERGAN MARCEL) 28 March 1997 see the whole document	1,4,6,14
A	WO 92 01585 A (BRITISH PETROLEUM CO PLC) 6 February 1992 see the whole document	1,30,43

1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 98/03594

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 9725551	A	17-07-1997	AU	1204897	A	01-08-1997
			GB	2324352	A	21-10-1998
US 4566565	A	28-01-1986	EP	0160429	A	06-11-1985
US 4751757	A	21-06-1988	NONE			
US 4647258	A	03-03-1987	SE	460062	B	04-09-1989
			AT	56236	T	15-09-1990
			CA	1240344	A	09-08-1988
			DK	476285	A	20-04-1986
			EP	0179028	A	23-04-1986
			FI	853860	A,B	20-04-1986
			GR	851415	A	20-02-1986
			JP	62165042	A	21-07-1987
			SE	8405248	A	20-04-1986
US 5564202	A	15-10-1996	NONE			
DE 2701181	A	20-07-1978	NONE			
WO 9716084	A	09-05-1997	AU	7480596	A	22-05-1997
US 5190248	A	02-03-1993	GB	2239177	A,B	26-06-1991
FR 2738998	A	28-03-1997	AU	7134796	A	17-04-1997
			EP	0853451	A	22-07-1998
			WO	9711616	A	03-04-1997
WO 9201585	A	06-02-1992	AU	8281391	A	18-02-1992